

## Volcanic Health Effects & Risk Assessment



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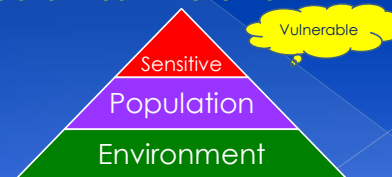
Presentation prepared for the  
California Air Response Planning Alliance  
May 31, 2012



University of Nevada, Reno  
Statewide • Worldwide

## Topics

- Volcanic Air Pollution Products
- Environmental Exposure Assessment
- Epidemiologic Assessment Methods
- Health Effects at Kilauea Volcano
- Population Health Prevention



## Volcanic Air Pollution (VAP)

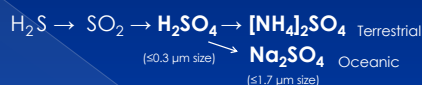
### Gases:

- Water vapor  $\text{H}_2\text{O}$
- Sulfur dioxide  $\text{SO}_2$
- Carbon dioxide  $\text{CO}_2$
- Hydrogen sulfide  $\text{H}_2\text{S}$
- Hydrogen chloride  $\text{HCl}$
- Hydrogen fluoride  $\text{HF}$
- Radon

### Fine Particles:

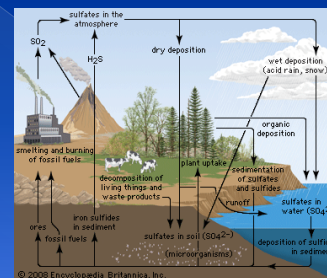
- Sulfuric acid aerosol
- Sulfates

### Ash



### PM + gas/aerosol

Natural & anthropogenic



### PM<sub>10</sub> - coarse particles

Filtered by upper airways

Eye irritation

Associated illnesses:

- rhinitis
- pharyngitis
- conjunctivitis
- exacerbation of asthma

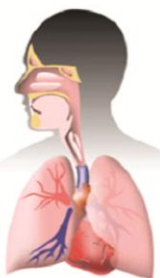
### Fine particles - PM<sub>2.5</sub> & PM<sub>1.0</sub>

Deposition in lower airways

Systemic absorption

Associated illnesses:

- bronchitis
- exacerbation of asthma/COPD
- pneumonia
- cardiovascular effects:
  - decreased heart rate variability
  - longer ventricular repolarization
  - increased blood viscosity



### Defense Mechanisms of the Respiratory System

1) Nasal filtration of particles/gases

Vulnerable populations:

- Children: mouth breathers, immature development of nares
- Athletes: mouth breathing

2) Mucociliary transport system

Vulnerable populations:

- Asthmatics: inflammation
- Smokers: damage to system

3) Bronchoconstriction

4) Alveolar macrophages

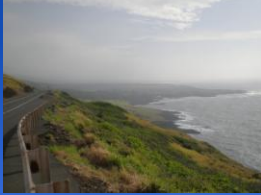
5) Cough mechanism

Wildfire Smoke Exposure: A Guide for the Nurse Practitioner. The Journal for Nurse Practitioners, 2012

Gas	Description	Health Effect
<b>SO<sub>2</sub></b>	Colorless Taste >0.350 -1.0 ppm Odor >67-4.7 ppm AEGL-1 = .20 ppm AEGL-2 = .75 ppm	Respiratory & dermal irritant, bronchoconstriction & inflammation, exacerbation asthma/COPD
<b>H<sub>2</sub>S</b>	Colorless Taste/Odor >.025 ppm olfactory fatigue LOAEL = 2 ppm Acute MRL = 0.07 ppm IDLH = 100 ppm 500 ppm - knockdown	Asphyxiant, URT irritant, bronchitis, asthma, death from acute respiratory distress syndrome - pulmonary edema - cardiac arrhythmias
<b>CO<sub>2</sub></b>	Colorless, Odorless 0.03% of air; >10% can be fatal heavier than air IDLH = 40,000 ppm	Asphyxiant, respiratory drive, causes CNS excitation followed by CNS depression
<b>HCL</b>	Colorless odor = 0.77-5 ppm Individualized heavier than air AEGL-1 = 1.8 ppm IDLH = 50 ppm	Respiratory & dermal irritant, bronchoconstriction & inflammation, RADS - pulmonary edema

AEGL = Acute Exposure Guideline Levels - 1 - non-disabling IDLH = Immediate Danger to Life or Health  
References: ATSDR, WHO, NRC - Acute Exposure Guideline Levels for Selected Airborne Chemicals

Compound	Description	Health Effect
$H_2SO_4$ aerosol	Colorless	Respiratory & dermal irritant; ↓pulmonary functioning; ↓mucociliary transport, ↓alveolar clearance & phagocytosis; exacerbation asthma/COPD
PM sulfates, ash	Colorful Haze	Restrictive pulmonary diseases (COPD), decrease pulmonary functioning, chronic bronchitis, pneumonia, exacerbation asthma/COPD, alveolar damage, cardiovascular effects, ocular effects



Volcanic smog  
"vog"  
40 km downwind  
of Kilauea

## Pyroclastic Fragments - Ash

Redoubt eruption March 2009

Chaiten Volcano, Chile

2010 Eyjafjallajökull Eruption

2008 Kilauea - USGS

## Environmental Exposure

1. What is the air pollution from the volcano?
2. How much? *Amounts, compared to ...*
3. What populations are at risk? *Locations*

## Environmental Exposure

- VAP exposure dependent on
  - > Location of eruption site(s)
  - > Volcanic emissions/products (quantity)
  - > Wind patterns (usual, other)
  - > Meteorology (scrubbing; inversions)
  - > Topography
  - > Distance from source (change in species)

## Environmental Exposure Assessment for Public Health

- Regional assessment vs. point source testing
- Remote sensing (NASA ARSET)
- Measurements
  - > Ambient & indoor
  - > Cross sectional vs. continuous
  - > Long-term average
  - > Real-time

MODIS 500m - Nov 21, 2010  
Terra Satellite - 10:30am

## Different pollutants in different locations

Regional Survey in 2003

Hot Spots

Published in Geology, 2005

## Cost, Time, Geographic Coverage

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SO<sub>2</sub> pulse fluorescence monitor

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Gold  
Standard

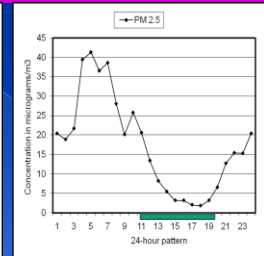
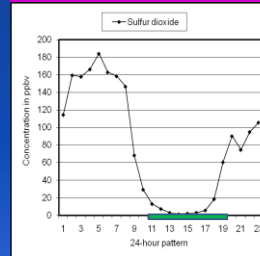


\$  
Accuracy +5%

## 24-hour patterns of SO<sub>2</sub> and PM<sub>2.5</sub> concentration averages during Trade Winds

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r = +.87

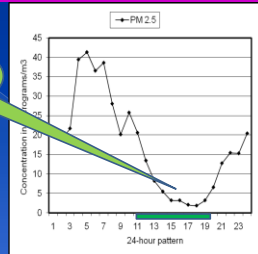
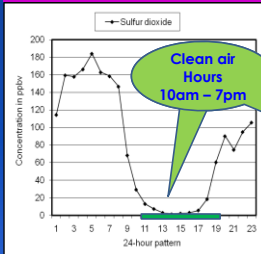
N Division of Health Sciences  
University of Hawaii, Manoa

Pahala Air Quality Monitor, data from State of Hawai'i

## 24-hour patterns of SO<sub>2</sub> and PM<sub>2.5</sub> concentration averages during Trade Winds

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## SO<sub>2</sub> Penetration Indoors

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Indoor Penetration	Locations
69%	School Cafeteria
59% - 85%	School Classrooms
56% - 68%	Plantation Houses
15% - 23%	Modern Houses
71% - 91%	Hospital Dayroom
65%	Hospital Clinic
85%	Emergency Department
8% - 25%	Air conditioning

Published: Geology, 2005;  
Family & Community Health, 2010

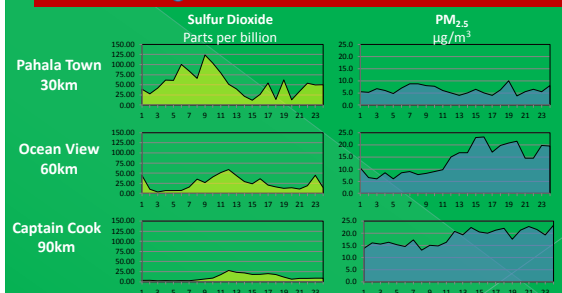
## Volcanic Activity Changes

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Summit  
2008 - presentPu'u O'o  
1980's  
Photo USGSNapau Crater 2011  
Photo USGS

## Kamoamoa Eruption Air Quality March 6-9<sup>th</sup> 2011 Average Concentrations over 24-hours

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## How much SO<sub>2</sub> is too much?

EPA - Before June 2010  
SO<sub>2</sub> 24-hour Average  
(Standard = **140 ppbv**)

EPA - NOW  
SO<sub>2</sub> 1-hour Average  
(Standard = **75 ppbv**)

World Health  
Organization's  
24 hr SO<sub>2</sub> guideline is  
**8 ppbv**

ATSDR –  
MRL SO<sub>2</sub> = **10 ppbv** for  
exposure <14days

Remember  
the sensitive  
populations

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## Poor Air Quality EPA & State of Hawai'i

Exceedances for sulfur dioxide gas

Year 2011 = **66%** of days exceeded

This year 2012 (January – April) =

- **93%** of the days exceeded
- Only **8** clean air days



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## Urban + VAP = Higher Impact

Consider location of cities with urban pollution problems to volcanic areas

Worst USA Cities List:

- #1: Bakersfield-Delano, CA
- #2: Hanford-Corcoran, CA
- #3: Los Angeles-Long Beach-Riverside, CA
- #4: Visalia-Porterville, CA
- #5: Fresno-Madera, CA



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## Health Effects

1. How many residents are having effects?
2. How much of a change in morbidity is occurring?
3. What is the impact on health care services?
4. Any long-term effects in population health?

## Methods for Epidemiologic Assessment

- Cohorts (based on exposure status)
  - › Comparison
- Baseline
  - › Existing data sets
  - › Prevalence Survey
- Prospective
  - › Adult & birth cohorts
  - › Sensitive members
- Retrospective

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## What to collect?

- Resident Self – reported health information
- Health survey by clinicians
  - › *The Volcano Health Questionnaire*
- Medical records
  - › EDs
  - › Health systems

- Acute signs & symptoms (prevalence)
- Medical Diagnoses (incidence)



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## What have we learned at Kilauea?

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Work with them

- Concerns from Hawaii's clinicians
- National Park workers have symptoms  
(NIOSH – Stephenson et al., 1991)
- Significant findings for ED respiratory illness  
(CDC – Mannino et al., 1996; U of H – Michaud et al., 2004; State of Hawaii, 2009)
- No evidence to date for cause of asthma  
(U of H – HICLASS Study ongoing)
- Increased self-reported symptoms in exposed population

Daily cough, eye irritation, runny nose, sore throat, wheezing, headaches, high blood pressure

(Published in Public Health, 2008; Nursing Research 2009)

## What have we learned?

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### Human Health

#### Higher risk of acute medical illnesses:

- ✓ Asthma attacks, bronchitis, pharyngitis, URI, cough
- ✓ Children (<15 years old) most affected

(Published in Journal of Toxicology & Environmental Health, 2008, 2010)

#### Quality of life affected in persons with chronic respiratory disease

#### Smokers report the most problems

(Published in Nursing Research, 2009)

## Findings for 2004-2006

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### Acute Bronchitis -

57% higher risk

Standardized cumulative incidence rates

Exposed cohort: **185.7** per 1,000

Unexposed cohort: **117.2** per 1,000

Relative Risk: **+ 57%**

1.57 (95% CI = 1.36-1.81)

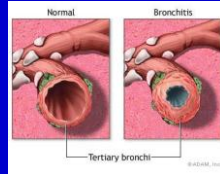
★ **Highest risk** in exposed children (0-14 yrs)

RR = **6.56** (3.16-13.60) "over 6 times higher risk!"

Exposed cohort current smoking (19%), unexposed cohort (27%)

**Disease BURDEN:**

**68 more visits in exposed area per 1,000 residents**



Journal of Toxicology & Environmental Health: Part A, November 2008

## Findings for 2004-2006

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### Acute Pharyngitis

"double the risk"

Standardized cumulative incidence rates

Exposed cohort: **234.2** per 1,000

Unexposed cohort: **102.4** per 1,000

Relative Risk: **+ 229%** 2.29 (95% CI = 1.85 - 2.84)

**Highest risk** in exposed children (0-14 yrs)

RR = **2.86** (1.72 - 4.74)

Exposed cohort current smoking (16%) unexposed cohort (31%)

**Disease BURDEN: 136 more visits in exposed area per 1,000 residents**



Published & presented at American Public Health Association Annual Meeting, Environmental Section, 2009

## Findings for 2004 - 2006

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### Acute upper respiratory infections

12% higher risk

Standardized cumulative incidence rates

Exposed cohort: **498.9** per 1,000

Unexposed cohort: **447.3** per 1,000

Relative Risk: **+ 12%** 1.12 (95% CI = 1.02 - 1.22)

**Highest risk** in exposed children (0-14 yrs)

RR = **2.29** (1.78 -2.95) "Double the risk"

**Disease BURDEN: 99 more visits for exposed children per 1,000**



Published & Presented at American Public Health Association Annual Meeting, Environmental Section, 2009

### Change in Eruption = ↑ VAP

	Kilauea SO <sub>2</sub> Emissions Average	SO <sub>2</sub> Air Quality in Kau Daily Average
2004 - 2007	1,700 m tpd – 1 point source	20.4 (±9.0) ppbv
2008 - April 2009	2,800 m tpd – 2 point sources	68.3 (±8.8) ppbv





## Acute exacerbations of asthma

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### Relative Risk Estimates

	2004-2007	Disease Burden	2008-April 2009	Disease Burden
Total Population	1.87 (1.50-2.33)	+21 per 1,000 residents /yr	3.19 (2.34 - 4.33)	+81 per 1,000 residents /yr
Children 0-14 years	5.10 (2.69-9.66)	+11 per 1,000 children /yr	8.72 (3.98-19.13)	+40 per 1,000 children /yr

4 x more cases with higher VAP

Published & Presented American Public Health Association Annual Meeting, Epidemiology Section, 2010



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## What can we do to prevent disease?

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### PUBLIC HEALTH FRAMEWORK

#### Primary Prevention:

Prevent onset

Promote general health

#### Secondary Prevention:

Detect early & treat promptly

#### Tertiary Prevention: Chronic Disease

Prevent progression of disease

Maintain Quality of life

## Primary Prevention

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### GOAL: Minimize Exposure to VAP

#### Encourage:

- ✓ Self Care on Heavy VAP Days: no exercise, stay indoors, AC
- ✓ Supplies in car/home (emergency & ash – protection)

#### Educate:

- ✓ Residents on the "Clean Air" website for current conditions
- ✓ All residents to use the "real time" air quality measurements from the Air Quality division on the internet
- ✓ Emergency Response Plan

Does everyone know what to do?

## Primary Prevention

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### GOAL: Minimize Exposure to VAP

#### Complete as needed:

- ✓ Disaster Shelter(s) & Hospital renovations

#### Develop:

- ✓ School's VAP Response Plan (equipment, training)
- ✓ Hospital's VAP Response Plan (air quality; influx of patients)
- ✓ Assistance to Senior Centers & Homebound persons
- ✓ Volcanic Emergency Response Plan (revisit, refresh, equipment)
- ✓ Communication with USGS volcanologists



## Secondary Prevention

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### GOAL: Identify early & treat

#### Screen:

- Heart & Lung disease
- Community health fairs
- Include spirometry in annual physical

#### Educate:

- Illness Symptoms in children

#### Treat: Smoking - nicotine dependency

Compared to adults - Children: more physically active breathe faster mouth breathe more air passes over lungs = Higher VAP dose





## Tertiary Prevention

### GOAL: Reduce Disease Progression

#### Persons with Asthma:

- ⊙ Ensure patients have a current **"Asthma Action Plan"**
  - > Use Guidelines from the National Heart Lung and Blood Institute
  - > Provide the area's clinicians with educational program from the Institute
- ⊙ Follow the California Department of Public Health's:
  - > "Guidelines for the Management of Asthma in California Schools"
  - > "Asthma Action Plan for Schools and Families"



## Tertiary Prevention

### GOAL: Reduce Disease Progression

#### Persons with heart disease:

- ⊙ Promote self care:
  - > Importance of taking their heart & BP medicine
  - > Communicating with their doctor or nurse practitioner
  - > Monitoring their BP
  - > Eating "Heart Healthy"

50% of residents at Kilauea were not taking their BP medicine

- ⊙ **California** has an Opportunity
- ⊙ Share lessons learned!

Thank you!

